

ECE 480 Design Team 4

Hot Strip Mill Center Line Tracking

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Executive Summary

The roughing section of a hot strip steel mill passes a length of heated steel through high pressure rollers several times to flatten the steel into a long strip. Inconsistent pressure applied by the two sides of the pressure rollers can cause the steel length to bend. This bending can cause the steel to impact the guards on either side of the rollers, damaging equipment and halting production.

The scope of this design project is focused on tracking the centerline of the steel strip through the roughing mill to monitor the steel's curvature. The plant will adjust roller pressure levels based on collected centerline data to correct the curvature and keep the centerline as constant as possible over the length of the strip.

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Introduction

The curvature that is caused by flattening the steel strip is referred to as cambering. Cambering occurs mostly in the roughing mill, where heated steel is pressed down by high pressure rollers to form a quarter inch thick strip. Due to changing temperatures and inconsistent pressure, a uniform press is not always obtained. When the compression process is non-uniform, the steel strip has a varying thickness from one side to the other, curving the steel. When a strip is curved, it can potentially run off of the rollers and damage equipment, resulting in hours of downtime.

To minimize cambering, our customer needs a centerline tracking device. When cambering starts to occur, there must be a system in place to detect variations in centerline fast and efficiently in order to take preventative measures. Due to the large-scale operations of steel mills, total prevention of the problem is not feasible and would result in downtime due to upgrades. Therefore, this project will not be designed to prevent the problem, but rather to detect the issue and alert an operator that curvature is present. The final design should incorporate hardware along with a software solution. The software will be compatible the operator interface during their monitoring of the process.

Background

In a hot strip mill, cambering is harmful to the steel production process because it dangers employees, damages equipment, wastes steel, and complicates production processes down the line which cost time and resources to correct. A reduction of cambering ensures a higher quality product for customers and other steel processes within the company. Preventing cambering reduces collisions between the steel strip and the roller guards, increasing operational safety for employees and preventing equipment damage and downtime. Tracking the centerline of the steel strip and correcting cambering as it is occurring in the roughing mill is crucial to maximizing production. When cambering is quickly detected and addressed, control systems can adjust the left and right pressures of the rollers independently to help counter the curvature of the steel strip. The American Institute of Steel Construction's (AISC) Code of Standard Practice for Steel Buildings and Bridges states that 1/8 inch of cambering for each 10 feet of steel length is acceptable.

Various companies make vision and sensor systems to detect and aid in the management of camber. EMG Automation GmbH specializes in the automation of continuous production processes in the metal industry. A product they offer, called hotCAM, is a high speed camera designed to measure camber of steel strips in the hot milling process. Delta is another company that specializes in applications to the steel industry. Delta has a sensor called the CCD Array Sensor TSP, which is typically used in centerline tracking applications. It works by detecting light and dark area. The steel is glowing and is light, while the rest of the area being captured is darker. The sensor has a diode array that switches on for light areas and remains off for dark areas. The output of light to dark area is given as an analogue output voltage from 0-10V. Software can be utilized to track the centerline of the steel with this device. Hardware applications such as these sensors require software and complex control systems to fully utilize their capabilities.

Design Specifications

Power

Our solution will be directly wired to supply power, preferably a 120/240VAC source. Battery power would require constant maintenance due to non-stop facility operation. Realistically, power consumption will be minimal compared to the power consumption of the hot-rolling process and will not be a concern.

Communication

Ethernet, profibus, and wireless are all feasible solutions depending on where the customer would like the alarm system to be placed. There will also be room for a direct wire connection to a controller that can be used to display a message or alarm in the operation room.

Camera/Laser Resolution

The resolution of the camera we use will be almost negligible. However, the rate of sampling (frames per second) is critical to success. Higher rates of sampling provide a more accurate and faster detection, but require more data to be stored. A lowered sampling rate provides a lower cost and storage requirement, but reduces the accuracy of the process.

Data Storage

Our solution will not have the ability to write the images to a disk space unless our customer would like it to do so. The program we use should be able to write data of how far off the steel is from the centerline to compare to previous samples. Since we will only be storing numbers, a few megabytes of storage will be adequate.

Environmental Tolerance

The hot strip mill is a very harsh environment for electrical equipment. Any hardware used needs to be able to withstand high temperatures and may call for a cooling system or shielding enclosure of our design. The steel strips are 800-1300 degrees Celsius. The maximum range of most production monitoring cameras is around 8 meters. Also, high pressure water is sprayed onto the steel in the roughing mill. If sensors are used near the roughing mill they need to be waterproof and debris resistant.

Conceptual Designs

Design 1: Centerline Tracking Production Monitor

Design 1 consists of implementing a high-end production camera to track the Dark-to-Light edge of the heated steel strip. Software designed by the team would use these two edges to know the location of the center of the steel strip. By recording and comparing data on the current and previous center points, the software will recognize and quantify the amount to which the steel has curved. If the steel's curvature exceeds the threshold, alarms will activate, alerting operators to the issue.

This design has been a favorite by the team due to its high accuracy, thermal resistance, and ease of assembly. The downside of the Centerline Tracking Production Monitor is the cost. High-end production monitors are well outside of the team's budget; however the sponsor may see that the quality and accuracy of this design may justify the cost.

Design 2: Laser Strip Edge Detection

Design 2 consists of implementing several laser sensors in a row over the steel strip. The sensors' beams would be broken in the presence of the steel strip and un-broken in the absence of the steel strip. Using the status of these laser sensors, software could be used to track the edges of the strip. The changing of the status of the sensors' beams would indicate a shift in the edge, and centerline, of the strip.

This design is considerably cheaper than the Centerline Tracking Production Monitor; however it includes a significant drop in accuracy. The range of the laser sensors is much less than that of a high-end camera, placing the sensors very close to the hot steel strip. Melting sensors would be difficult to avoid and would require an extensive heat removal process and shielding.

Design 3: Pressure Sensor Weight Shifter

Design 3 consists of utilizing pressure sensors already existing within the production line. The pressure of the rollers is checked by pressure sensors to confirm values and ensure that no equipment is malfunctioning. There is one pressure sensor on either side underneath the pressure roller. As the strip runs through the roller, it passes over these sensors and is essentially weighed. By subtracting the force applied by the upper roller, we can find the weight of each side of the steel strip and monitor variations with software.

This design would be cheap, only implementing software, but would be slow to react to changes and would not actually track the centerline of the strip. This design would only track the center of mass of the strip relative to the center of the rollers.

Feasibility Matrices (To be completed at a later date)

Feasibility

Design	Cost	Sampling Rate	Complexity	Durability	Average
Centerline Tracking Production Monitor					
Laser Strip Edge Detection					
Pressure Sensor Weight Shifter					

Risk Analysis

To solve the problem, a solution in which has high resistance to heat, water, and debris must be implemented. If the camera is not able to withstand these conditions, an enclosure may have to be engineered. Also, at current stage of the project, an ideal location to install the camera to track the centerline of the steel strip is unknown. The camera could be mounted by the finishing stands.

Project Management

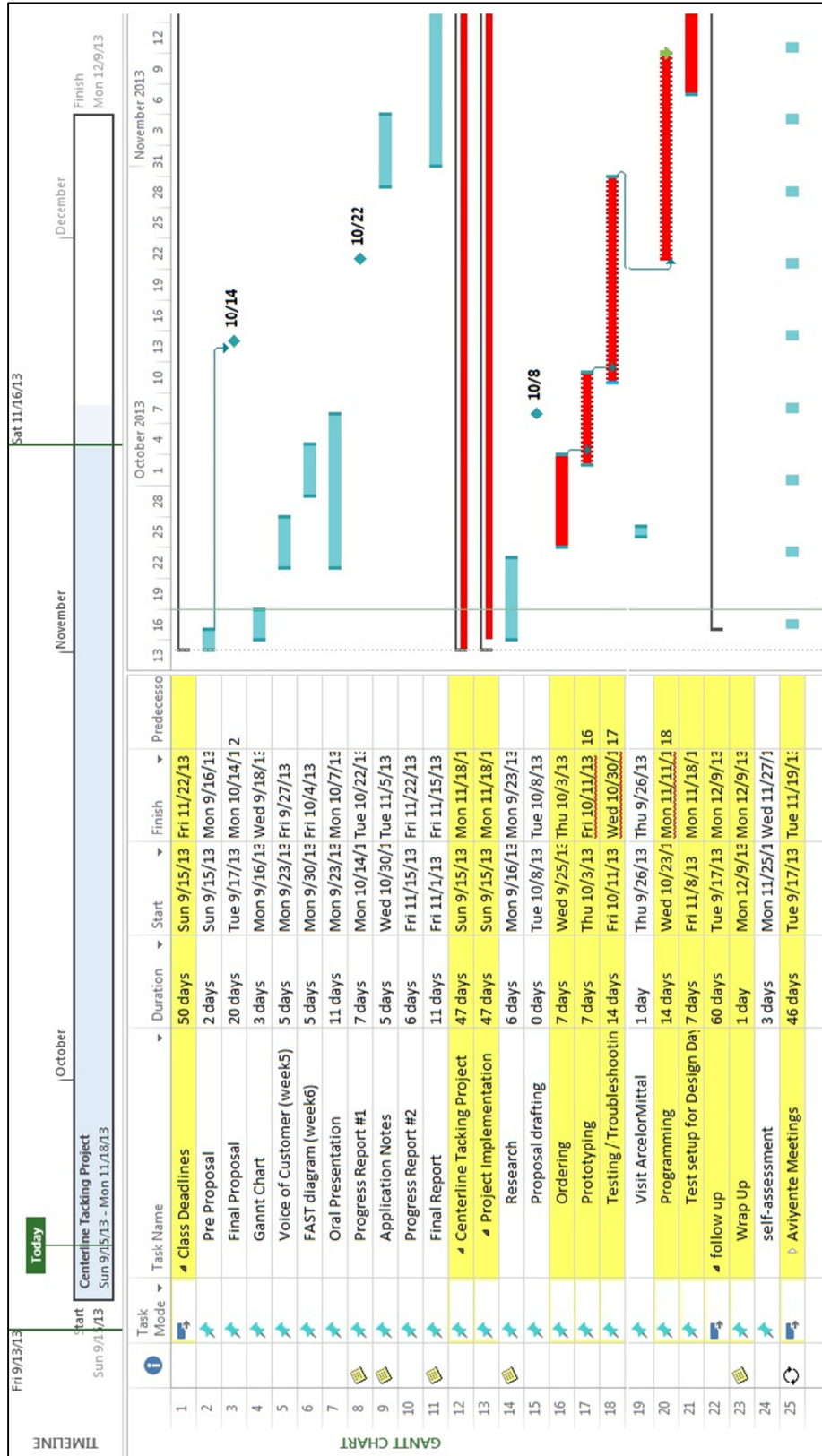
The table below describes the role of each member in the team. However, these roles will not forbid other members from assisting each other. They are meant for smooth functioning of the team to meet deadlines of the project. All members will contribute to the project equally and are to ensure that the other member's tasks are completed for any particular deadline.

Personnel Roles

Bryan Blancke	Non-Technical Role: Team Management Oversees the operation of the project. Responsible for ensuring all members work together efficiently. Manages methods and systems for effective team communication and information sharing. Ensures quality of work. Cohesively coordinates team members and their individual responsibilities to meet deadlines of the project. Technical Role: Demonstration Bench - Mechanical Design and Build Demonstration Bench in collaboration with the ECE shop to demonstrate the significance of the design project. Acquire materials to simulate hot strip mill operations and integrate the team project into the system to show how it will perform in industry. A video of the demonstration must be recorded to show on design day.
Mark Heller	Non-Technical Role: Document Preparation Responsible for ensuring each deliverable has all of the necessary information, such as final proposal and final report. Maintain document standards and organization. Technical Role: Demonstration Bench - Electrical Determine peripheral hardware (e.g., power supplies, cables, and enclosures) required to complete design. Design, optimize, and construct project control enclosure. Responsible for mechanical and electrical CAD drawings.

Daniel Kim	Non-Technical Role: Presentation Preparation Coordinates oral communication for team presentation and preparation of the poster for the design day. Technical Role: Hardware Specialist Responsible for acquiring camera/sensor and testing the functionality of the equipment. Assess the feasibility of the equipment for the project.
Jeremy Martin	Non-Technical Role: Lab Coordinator Coordinates ordering parts and ensures the cleanliness of the lab. Schedules lab meeting times and coordinates build phases of the project. Technical Role: Software integration Establish electronic communication with equipment via Ethernet. Creation of Demonstration Bench Human Machine Interface and data collection scheme. Responsible for maintaining a standard in code work for ease of comprehension.

Gantt Chart



Project Cost

The team has been funded with \$500. The majority of the budget will be spent on purchasing a camera/sensor for the project. Initially, the team looked into purchasing a state of the art camera, but that will go over team's budget. Consequently, it is more feasible to purchase a cheaper, but still high quality, camera. It is estimated to cost anywhere from several hundred dollars up to a thousand dollars. It is likely the team may require additional funding for the project. Besides acquiring the camera, the other necessary parts would put a significant strain on the budget. A lower cost solution using less expensive laser sensors will be investigated.

Resources

EMG hotCAM Camber and position measureme. 2013. youtube. Web. 18 Sept. 2013.
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Hot Rolling Mill. youtube. Web. 18 Sept. 2013.
<<http://www.youtube.com/watch?v=AuuP8L-Wppl>>.

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<<http://www.omega.com/pptst/M12C.html>>.

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<<http://www.deltasensor.eu/en/catalog/sensors/linear-cameras/tsp.html>>.